Evaluating acoustic technologies to monitor aquatic organisms at renewable energy sites

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LONG-TERM GOALS

The long-term goal of this program is to quantify and evaluate the ability of three active acoustic technologies (echosounder, multibeam sonar, and acoustic camera) to characterize and monitor animal densities and distributions at a proposed hydrokinetic site. Data from stationary, bottom-mounted acoustic packages will be compared to that from a mobile, surface survey. Results from this study will inform the choice, deployment, and data analyses of acoustic instrumentation use at marine hydrokinetic (MHK) sites.

OBJECTIVES

Objectives of this research include: collecting temporally-indexed data from an echosounder, multibeam sonar, and an acoustic camera; to perform a mobile acoustic, seabird/marine mammal, and midwater trawling survey to characterize macroinvertebrate, fish, seabird, and marine mammal spatio-temporal distributions at the study site; to compare and contrast stationary instrument with mobile acoustic survey data for evaluation of each instrument type; and to provide recommendations for deployment and data acquisition procedures at marine hydrokinetic sites.

APPROACH AND WORK PLAN

Using active acoustic technologies to map, count, and size distributions of fish and zooplankton is common in fisheries science. The use of active acoustics to monitor marine hydrokinetic sites is a new application and appropriate analytic methods have yet to be developed, evaluated, or standardized. The intent of this project is to reconfigure existing acoustic technologies to be deployed as autonomous instrument packages, collect spatially- and temporally-indexed data at a proposed marine hydrokinetic site, and to compare and contrast data from autonomous, bottom-mounted packages, to acoustic and net catch data collected during surface surveys of the same site. Bottom-mounted packages represent three current acoustic technologies: splitbeam echosounder, multibeam sonar, acoustic camera. Surface surveys used splitbeam echosounders and a multibeam sonar. Acoustic data was groundtruthed using catches from a midwater trawl. Seabird and marine mammal counts were collected concurrently during the surface survey. Bottom instrument packages were deployed for a minimum of a full lunar cycle and surface surveys were conducted during day, dusk, and night periods for two weeks at the start and end of the bottom package deployments.

A large team of individuals are contributing to this project. Deployment and recovery of acoustic moorings and ADCP data are being led by Drs. Jim Thomson (Applied Physics Laboratory, University of Washington) and Brian Polagye (Mechanical Engineering, University of Washington). Acoustic surface sampling is coordinated by Dr. John Horne (School of Aquatic and Fishery Sciences, University of Washington). Marine mammal and fish sampling are being coordinated by Kurt Fresh and Dr. Brad Hanson (National Marine Fisheries Service, Northwest Fisheries Science Center). Three vendor partners are responsible for instrument configuration and data acquisition: acoustic camera -- Bill Hanot, SoundMetrics; splitbeam echosounder -- Jim Dawson, BioSonics; and multibeam sonar -- Paul Jublinski, RESON.

In the upcoming year, analyzing data is the focus of the work plan. All acoustic data has been delivered by the vendors and pre-processing of the surface survey data has begun. Fish trawl catch data has been tabulated and species composition is being compared to that reported in a 1970's literature review. ADCP data from the bottom platforms have been retrieved and analyzed to provide tidal conditions (i.e. speed, direction, turbulent intensity) as additional context for acoustic and trawl data.

WORK COMPLETED

During the reporting period, the design for surface surveys and bottom-mounted sampling were conceived and finalized; autonomous acoustic instrument packages were designed and fabricated; surface surveys were conducted and the autonomous packages were deployed and retrieved; all data was recovered from instruments, archived, and data pre-processing has started. Figure 1 shows the surface survey design (left) centered on the proposed Admiralty Inlet tidal power site, and the deployment locations of the acoustic instrument packages (right). Example data from all instruments was incorporated into a data fusion – visualization package to demonstrate the potential use of the software.

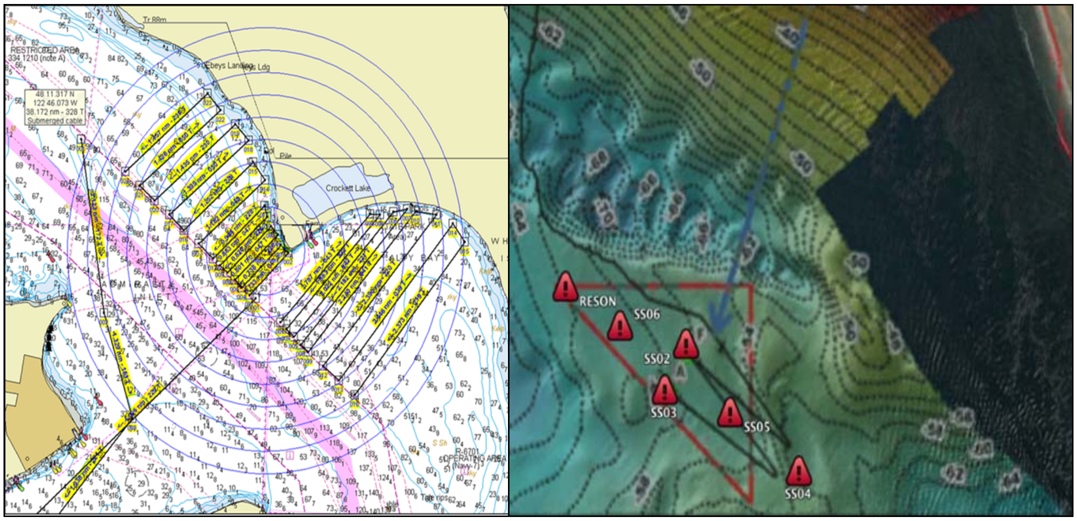

Figure 1. Surface survey design (left panel) and location of bottom instrument packages in Admiralty Inlet, WA.

RESULTS

The research team found that it is possible to adapt existing acoustic instrumentation for autonomous deployments in high-flow environments, but that additional scrutiny is needed to ensure that power supplies meet sample design requirements, and that data quality matches expectations. We found that available power constrains acoustic sample density more than data storage during autonomous deployments. Figure 2 shows a picture of the back deck of the RV Robertson with autonomous acoustic instrument packages ready for deployment. Acoustic packages included a multibeam sonar (top), an acoustic camera (middle left), a splitbeam echosounder (middle right), and an Acoustic Doppler Current Profiler (ADCP) (lower left). With no way to check operations or data quality once deployed, data quality from the autonomous multibeam sonar, acoustic camera, and the splitbeam echosounder did not match that of equivalent surface deployments. Increased pre-deployment testing and alternate parameter settings will reduce or eliminate data quality problems.

Figure 2. Back deck of RV Robertson showing acoustic instrument packages ready for deployment.

As expected, biomass densities distributions were variable across space and over time. Contrary to expectations, there did not appear to be high correlations between tidal flow and densities of seabirds, marine mammals, fish, or macro-invertebrates during data acquisition, but results remain to be quantified. If this pattern holds, then mitigation of potential biomass strikes with MHK devices will not be able to use tidal state as a predictor.

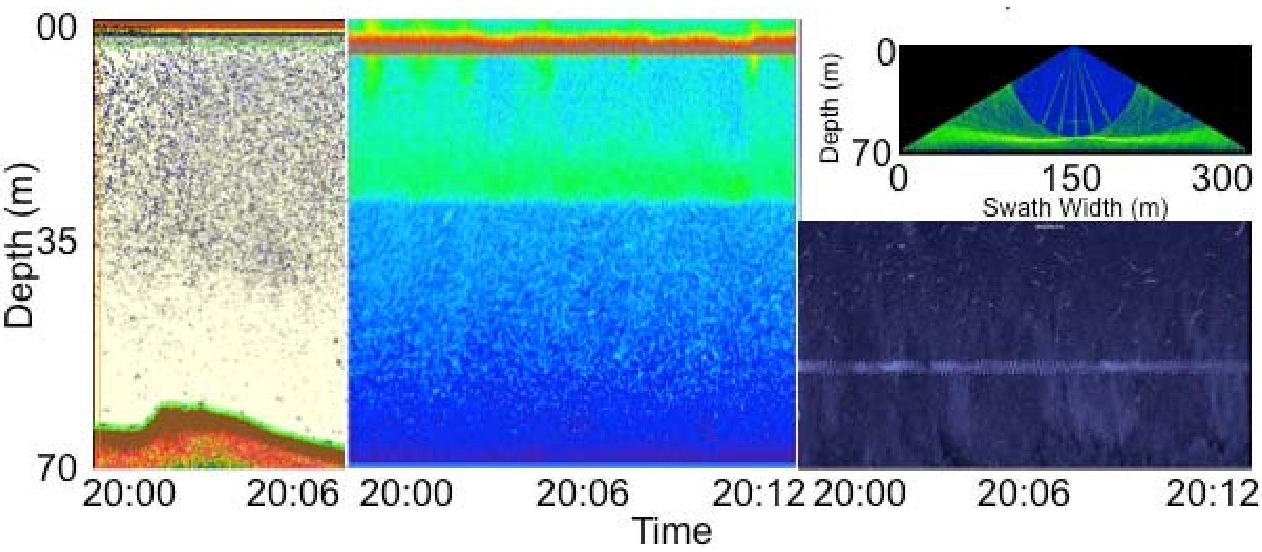

Figure 3. Representative echograms from acoustic instruments: Simrad echosounder (left), Biosonics echosounder (center), Simrad multibeam sonar (upper right), DIDSON acoustic camera (lower right).

Figure 3 depicts four sets of data collected in close proximity over the same time period on June 4, 2011. The left panel shows the echogram from the Simrad 38 kHz echosounder with a dense distribution of small targets in the upper 35 m of the water column and dispersed larger targets below the layer. The middle panel contains the Biosonics 200 kHz echosounder echogram from the same period. Four surface aggregations are visible within the first 6 minutes and target densities decrease from surface to bottom. The two layer color representation is due to a second surface echo received at the transducer. The upper right panel contains a Simrad multibeam sonar echogram from a single transmission. A small aggregation can be seen near bottom. The four vertical lines are due to interference within the sonar transducer. The lower right panel contains the echogram from the DIDSON acoustic camera. Individual targets can be seen in the upper water column with plumes of small targets originating from the bottom. The horizontal band across the echogram is due to a second surface echo received at the transducer.

Biomass in trawl catches was consistent with relative acoustic backscatter intensities observed in the surface deployed echosounder. Species diversity differed depending on trawl date, time of day, and location. We caught and identified 43 fish species, with another 9 specimens that could not be definitively identified when caught. Five fish species (soft sculpin (*Psychrolutes sigalutes*), copper rockfish (*Sebastes caurinus*), spotted ratfish (*Hydrolagus colliei*), Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasii*)) dominated trawl catches by number and by mass during surface surveys in May and June. Species composition in combined catches represented approximately 20% of that compiled in a review of 212 fish species reported for Admiralty Inlet (DeLacy et al. 1972). We attribute the low percentage in total number of species observed to our limited seasonal sampling and the use of a single gear type (i.e. small midwater trawl).

Distribution and abundance patterns were observed in seabird and marine mammal count data. Nine species of seabirds were identified during surveys. Rhinoceros auklets (*Cerorhinca monocerata*) and pigeon guillemots (*Cepphus columba*) were the most abundant, followed by marbled murrelets (*Brachyramphus marmoratus*), common murres (*Uria aalge*), pelagic cormorants (*Phalacrocorax* *pelagicus*), western grebe (*Aechmophorus occidentalis*), common merganser (*Mergus merganser*), common loon (*Gavia immer*), and ancient murrelet (*Synthliboramphus antiquus*). Greater overall densities were observed in the northern grid primarily due to rhinoceros auklets. In the southern grid, pigeon guillemots were more abundant, along with pelagic cormorants and marbled murrelets. The north grid also contained greater densities of marine mammals. Four species of marine mammals were identified -- harbor porpoises (*Phocoena phocoena*) and harbor seals (*Phoca vitulina*) being the most abundant, followed by Steller sea lions (*Eumetopias jubatus*) and California sea lions (*Zalophus californianus*). June surveys averaged greater overall densities of both seabirds and marine mammals. Pigeon guillemots, pelagic cormorants, common mergansers, and western grebes were more abundant in May.

Actual tidal times, speeds, and magnitudes do not always match those predicted by NOAA tide/current tables in high-flow tidal channels. Data from the bottom mounted ADCP instruments showed that tidal velocities varied with depth, were faster than predicted (max. 4 ms^{-1}, 8 knots), and that tidal state transition speeds (min. 0.5 ms^{-1}, 1 knot), times, and durations did not match NOAA published values. Figure 4 depicts water flow (units ms^{-1}) as a function of depth (units m) through the water column (left panel) for June 7, 2011. The right panel depicts horizontal water velocity (speed upper panel, direction lower panel) at 8 m above the seabed from early May through early June 2011. Diel phasing (i.e. diurnal inequality) varies through the lunar cycle.

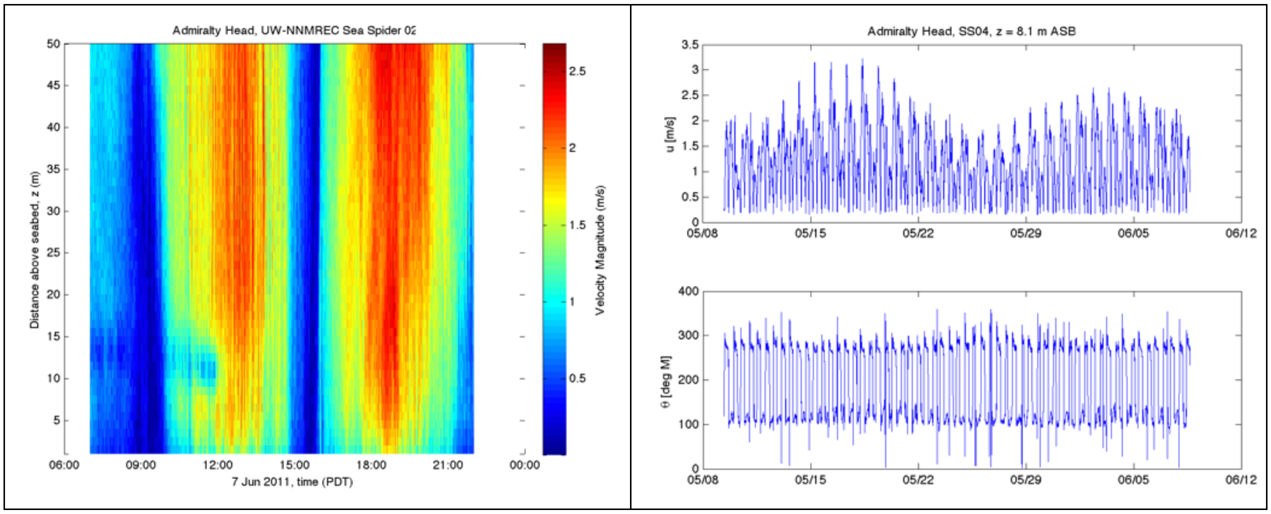

Figure 4. Water flow at Admiralty Inlet, WA showing velocity magnitude (left panel) on June 7, 2011; and velocity (speed upper, direction lower) for the May – June sampling period (right panel).

Increased water flows affected our surface sampling in two ways: increased turbulence in the acoustic record and decreased time windows to deploy the midwater trawl. Acoustic sampling in high flow environments increases noise in the data set from the surface to a maximum of ~50 m. Distinguishing biota from turbulence noise is an additional challenge when processing surface survey acoustic data. Increased water flow speeds narrowed the temporal window around slack tides that was available to fish with the midwater trawl. The maximum net rate that the trawl could be fished was 3.5 knots. Given a towing speed of 2.5 knots, the maximum current speed when trawling (always into the current) restricted fishing to times when water speeds were approximately 1 knot.

IMPACT AND APPLICATIONS

National Security

If marine renewable energy installations reach commercial scale or are used to supply power to strategic assets, then the ability to monitor biologics and to distinguish biologics from anthropogenics will increase the ability to determine threat risk to marine hydrokinetic infrastructure.

Economic Development

Two of the three partner vendor partners that have developed products for use in this project are now commercially marketing the products. BioSonics combined a new system controller with a pressure housing and is now marketing an autonomous echosounder package. RESON developed a bottom platform and power supply system that can be used as a mount for any instruments in their product line and now offers this platform as a commercial autonomous mounting system. Software programming by SoundMetrics for the instrument used in this project has been used in the development of a new operating system for the second generation acoustic camera, now commercially available.

Quality of Life

An additional objective of this project is to recommend general equipment choice, deployment, and biological monitoring strategies for marine renewable energy sites. These recommendations should improve accuracy and help standardize environmental monitoring in an emerging, ‘green’ energy industry.

Science Education and Communication

A graduate student is being trained in the use of active acoustics, survey design, and environmental monitoring during this project. Results of this project have been reported by print, radio, and television media to the public, and presented at scientific conferences. Additional discussions have been held with representatives from the Department of Energy and the National Science Foundation to identify needs for environmental monitoring and the necessary coincident graduate student training to provide private industry and government with a pool of people capable of measuring and evaluating biological data used in the development and monitoring of marine hydrokinetic sites.

TRANSITIONS

Economic Development

See Economic impacts above

Science Education and Communication

Results of this project are being communicated to the marine hydrokinetic science community and potentially used to compare and contrast results with at least two other projects located in Maine and Nova Scotia, Canada with the aim of deriving best scientific practices for environmental monitoring. An acoustic training course will be offered to graduate students and staff involved with the other two projects.

RELATED PROJECTS

Three projects are relevant to work included in this project: development of echosounder controller for autonomous deployment, Admiralty Inlet monitoring, monitoring for strike of turbine blades. First, the

Northwest National Marine Renewable Energy Center (NNMREC), a DOE-funded research center, partnered with BioSonics Inc. in 2009 to develop the first-generation controller for autonomous echosounder deployments. This development was leveraged by BioSonics for use in this project. Second, NNMREC has been working with Snohomish PUD to characterize the biological and physical environment in northern Admiralty Inlet ahead of a proposed hydrokinetic turbine deployment in 2014. Sea Spider instrumentation packages have been deployed at this location since 2009. These deployments have allowed NNMREC to demonstrate the mechanics of instrumentation deployment and retrieval in high-flow environments, and then were applied to similar deployments in this project; and improved the understanding of tidal currents at this location, which was used to provide more accurate tidal predictions for trawls than possible using NOAA tide and current tables. All data collected is posted at http://depts.washington.edu/nnmrec. Finally, NNMREC is developing a stereo imaging system to monitor potential interactions between operating tidal turbines and pelagic nekton. This system will be deployed with Snohomish PUD's hydrokinetic turbines in 2014. Data collected from this project will help define the species composition likely to be observed in the vicinity of the turbines.

REFERENCES

DeLacy, A.C., Miller, B.S., and S.F. Borton. 1972. Checklist of Puget Sound Fishes. Washington SeaGrant Publication 72-3. 43 p.

OUTREACH MATERIALS

Two print articles, one public radio report, and one television piece were broadcast as a result of a media day held in conjunction with the autonomous acoustic package recovery. Articles can be accessed through:

http://www.peninsuladailynews.com/article/20110609/news/306099990/admiralty-inlet-ocean-life-studied-to-accommodate-potential-undersea

http://www.kitsapsun.com/news/2011/jun/08/data-from-puget-sounds-depths-tell-of-marine-at/

http://news.opb.org/article/researchers-study-potential-impact-tidal-power-turbines/
http://earthfix.kuow.org/energy/article/researchers-study-the-potential-environmental-impa/

http://www.king5.com/news/environment/Tidal-Energy-123507024.html